Increase of Adolescent Cancer Diagnoses in the U.S. Correlated to Cell Phone Subscriptions

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ABSTRACT

Epidemiology data for 46,997 cancer diagnoses of children aged 0-10 from 1973-2013 in the U.S. were correlated with industry data for U.S. cell phone subscriptions. Cumulative diagnoses by age 10 rose 323% from 132.9 to 562.4 per million live births from 1973 to 2003 (through 2013). The highest correlation was for 7 and 8-year-olds with $R^2 = 0.988$ and $p < 0.00001$. Sixteen histologies were reviewed, with glioma (i.e., brain tumors) having the highest correlation with $R^2 = 0.985$, followed by neuroepitheliomatous neoplasms with $R^2 = 0.888$, and Hodgkin's lymphoma with $R^2 = 0.852$, all $p < 0.00001$. Several other histologies also had significant positive correlations in bone marrow cells and lymphocytes, while malignant lymphoma was found to be uncorrelated. These findings raise questions about the current electromagnetic emissions safety standards utilized by the consumer electronics industry, and the effects of electromagnetic emissions on human tissues and intracellular processes.

Introduction

This paper documents an increased rate of cancer diagnosis in U.S. adolescents up to age 10 from 1973 to 2013 and correlates this increase with industry data for U.S. cell phone subscriptions.

During recent analysis of U.S. epidemiology data that spans 1973 to 2013 and correlation of cumulative cancer diagnoses by year of birth with cumulative DNA damage, the authors observed a variable trend of increasing diagnosis rates that starts in the mid-1980s, increases in rate in the 1990s, and only starts to slow near 2010 [1]. Since cancer diagnoses are relatively rare in children, an increase in adolescent diagnosis rates may be overlooked when looking at diagnosis rates of the entire population. Similarly, methodologies that bin different ages and years of birth obfuscate changes in rates of cancer diagnosis. Intrigued, we attempted to identify any environmental variables that could explain this substantial increase in cancer diagnosis rates of U.S. adolescents. A significant environmental change would seem to be required to have such a dramatic adverse change on diagnosis rates. Coincidentally, a recent survey of 153 cancer registries confirms that childhood cancer diagnoses have increased throughout the world since the 1980s with the exception of sub-Saharan Africa [2].

Non-ionizing radiofrequency radiation was classified as a possible human carcinogen in 2013 by the International Agency for Research on Cancer (IARC) [3]. A recent draft carcinogenesis study of cell phone radiation exposure by the U.S. National Toxicology Program identified higher cancer rates due to exposure [4]. Although the exact mechanisms for how non-ionizing radiation

can cause cancer are not yet known, a wide frequency range of interaction with DNA has been identified due to fractal antenna characteristics at the molecular level which results in complex reactions [5]. Nitrogen substitution due to Carbon-14 decay in DNA can result in weakened rings in nitrogenous bases, and it is not yet understood how weakened strands are affected by electromagnetic radiation during transcription [6]. Furthermore, if genetic repair mechanisms are affected by electromagnetic radiation, it could result in additional pathogenic mutations.

Several epidemiological studies on adult mobile phone use and cancer have been published, showing both negative and positive associations. Five studies showing no association reported use from 1.8 to 2.8 average years with a follow-up one year later, or use from 3 to 6 years with no follow-up, without allowing for a latency to diagnosis [7,8,9,10,11]. Of three studies showing a positive association, between 3 and 7 years of use was included, and two allowed for 5 years of latency to diagnosis, while one allowed for 10 years [12,13,14]. Regardless of the finding, estimating the actual exposure was a persistent challenge in these studies. While some types of cells are continuously regenerating, such as lymphocytes, other types of cells regenerate at a rate near 10 years, including adipocytes and osteocytes, while glia and neurons do not regenerate, except for a small number of neurons in each hippocampus [15,16,17,18,19]. Some pathogenic damage to these types of cells may only be expressed after a long latency in adults, whereas in children these tissues are all growing relatively rapidly and pathogenic damage may be expressed with less latency. Despite lacking a precise mechanism for causality, any measurable positive association due to exposure will eventually be evident in the population as market saturation occurs.

Results

Cell phone subscriptions in the U.S. increased from a negligible number prior to 1985 to over 310 million in 2013 (Fig. 1). In 1989, for the first time, more than one million new subscriptions were added per year. By 1996, growth was over ten million subscriptions per year. Growth of nearly twenty million subscriptions per year occurred between 2000 and 2007, peaked at 25.9 million in 2006. Having exceeded 300 million subscriptions in 2012, growth slowed to under ten million subscriptions per year for the first time since 1996. However, market growth was still over five million subscriptions per year in 2013.

During this period, there was a substantial increase of cancer diagnosis rates in adolescents (Fig. 2), increasing from 132.9 diagnoses per million live births in 1973 by the age of ten (i.e., through 1983), to 562.4 diagnoses per million live births in 2003 by the age of ten (i.e., through 2013). This represents an overall 323% increase of diagnosis rates. By 1985, the diagnosis rate increased 29% to 167.9. In four short years, by 1989 the diagnosis rate had increased to 68% to 223.5. Over the next ten years, through 1999, the rate increased nearly 23% per year, to 543.3. The rate of increase appears to slow after 2000, rising to 562.4 in 2003 (for diagnoses in ten-year-olds through 2013). This trend of a gradual rise, rapid rise, and then slowing increase appears to be similar when comparing Figs. 1 and 2.

The correlation between the increase of cumulative diagnoses of cancer in adolescents for each year of birth 1973-2013 and year of age up to ten with the increase in U.S. cell phone

subscriptions are provided in Tab. 1. The increase in diagnosis rates for each age group is highly correlated with U.S. cell phone subscriptions, with $R^2 \geq 0.836$ for ages 0 and 1, and $R^2 \geq 0.970$ for age 5 through 10, with a peak of $R^2 = 0.988$ for ages 7 and 8, all with $p < 0.00001$. This correlation for ten-year-olds is illustrated on Fig. 3. (See Extended Data Table 3 for more detail.)

The correlation between the increase of cumulative diagnoses by histology in adolescents for each year of birth 1973-2003 and up to the age of ten (i.e., through 2013) with the increase in U.S. cell phone subscriptions are provided in Tab. 2. The increase of diagnosis rates by histology were also in several cases highly correlated with U.S. cell phone subscriptions, peaking with glioma (brain tumors) with $R^2 = 0.985$ and $p < 0.00001$, based on 7,176 diagnoses. Also, very highly correlated were neuroepitheliomatous neoplasms with $R^2 = 0.888$, from 4,027 diagnoses, followed by Hodgkin's lymphoma with $R^2 = 0.860$ (both $p < 0.00001$), from 699 diagnoses. These high correlations of glioma and Hodgkin's lymphoma are illustrated on Fig. 4 and 5. (See Extended Data Tables 4 & 5 for more detail.) Four other histologies also had substantive high correlations better than $R^2 \geq 0.753$ and $p \leq 0.00001$ (i.e., osseous and chondromatous neoplasms, miscellaneous bone tumors, mature B-cell lymphoma, and T & NK-cell lymphoma). Positive correlations were also found with five other histologies, with $R^2 \geq 0.521$ and $p \leq 0.0024$ (i.e., liposarcoma, precursor cell lymphoblastic lymphoma, meningioma, nerve sheath tumors, and angiosarcoma). Too few diagnoses of giant cell tumors, odontogenic tumors, and hepatocellular carcinoma were found for substantive correlations (i.e., $p >= 0.1$). Based on 215 diagnoses, malignant lymphoma was not correlated with U.S. cell phone subscriptions ($p = 0.0235$).

Table 1: Increase of cumulative diagnoses in U.S. correlated with U.S. cell phone subscriptions 1973-2013

Diagnoses	Age	Birth Years	# Years	Correlation w/ U.S. cell phone subscriptions		
				R	t	p
6,665	0	1973-2013	40	0.914	13.89	0.0000
12,289	1	1973-2012	39	0.932	15.66	0.0000
18,031	2	1973-2011	38	0.954	19.07	0.0000
22,843	3	1973-2010	37	0.968	22.69	0.0000
26,404	4	1973-2009	36	0.976	26.09	0.0000
28,825	5	1973-2008	35	0.985	32.73	0.0000
30,482	6	1973-2007	34	0.991	41.50	0.0000
31,664	7	1973-2006	33	0.994	50.30	0.0000
32,517	8	1973-2005	32	0.994	50.61	0.0000
33,263	9	1973-2004	31	0.992	42.20	0.0000
34,042	10	1973-2003	30	0.989	35.04	0.0000

Table 2: Increase of cumulative diagnoses in U.S. by histology by age ten correlated with U.S. cell phone subscriptions 1973-2013

Tissue	Histology	Diagnoses	Correlation w/ U.S. cell phone subscriptions		
			R	t	p
Adipocytes	Liposarcoma	30	0.722	3.76	0.0024
Bone Marrow Cells	Osseous and Chondromatous Neoplasms	541	0.868	9.39	0.0000
	Giant Cell Tumor	3	0.372	0.40	0.7570
	Miscellaneous Bone Tumors	409	0.875	9.73	0.0000
	Odontogenic Tumors	4	0.113	0.16	0.8866
Hepatocytes	Hepatocellular Carcinoma	10	0.493	1.50	0.1777
Lymphocytes	Malignant Lymphoma	215	-0.406	-2.39	0.0235
	Hodgkin's Lymphoma	699	0.927	13.34	0.0000
	Mature B-Cell Lymphoma	820	0.923	12.90	0.0000
	Precursor Cell Lymphoblastic Lymphoma	432	0.863	9.22	0.0000
	T & NK-Cell Lymphoma	226	0.913	10.28	0.0000
Neurons & Glia	Glioma	7176	0.992	43.55	0.0000
	Meningioma	54	0.803	4.86	0.0003
	Nerve Sheath Tumors	249	0.856	7.94	0.0000
	Neuroepitheliomatous Neoplasms	4027	0.942	15.17	0.0000
Vascular Endothelial Cells	Angiosarcoma	93	0.838	7.36	0.0000

Figure 1: U.S. cell phone subscriptions 1983-2013

Industry statistics indicate the number of U.S. cell phone subscriptions increased from 340 thousand in 1985 to over 310 million in 2013.

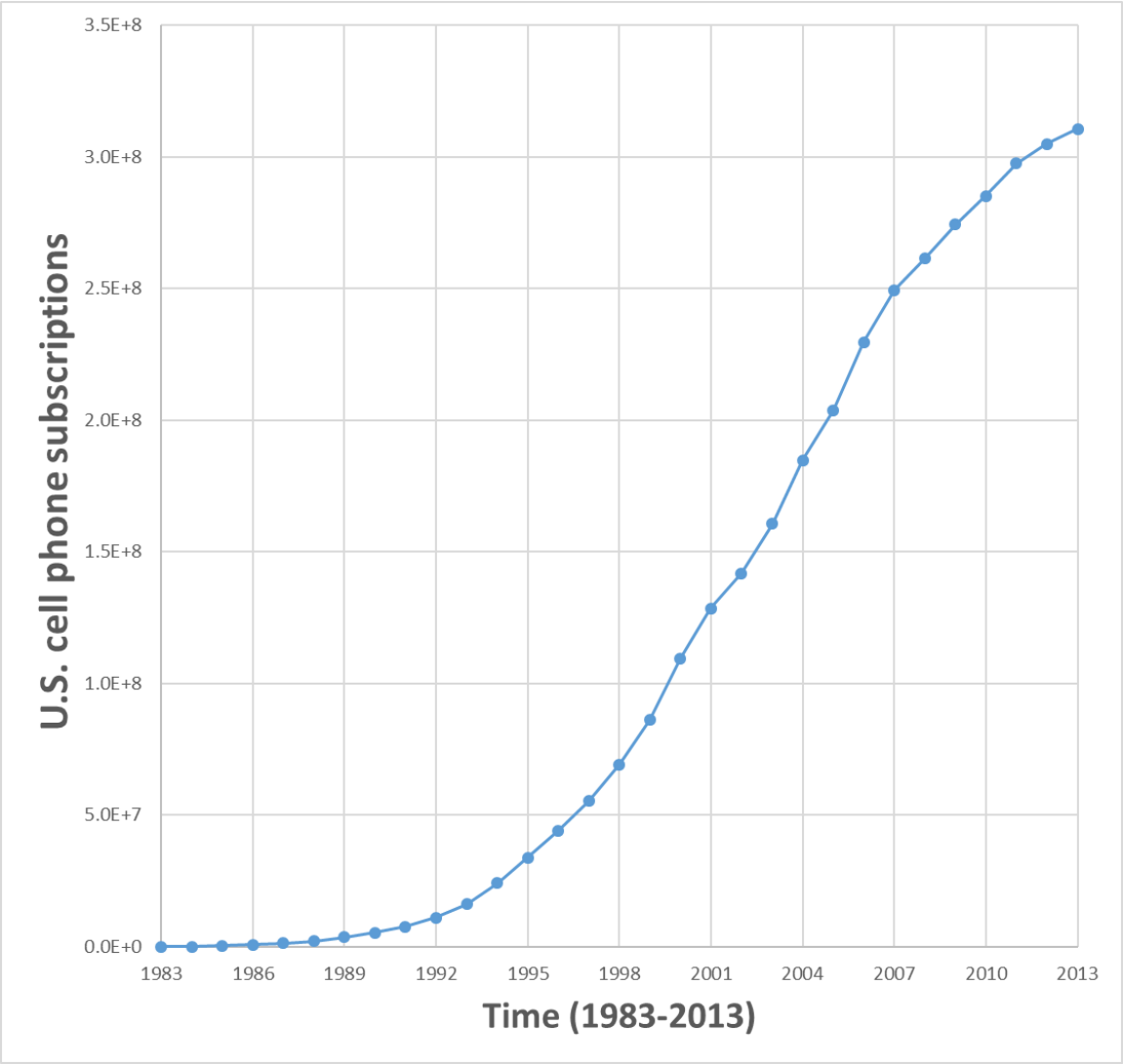


Figure 2: Increase of cancer diagnoses by the age of ten in the U.S.

Diagnoses of cancer in the U.S. per year of birth by the age of 10 increased from 132.9 to 562.4 per million live births from 1973 to 2003.

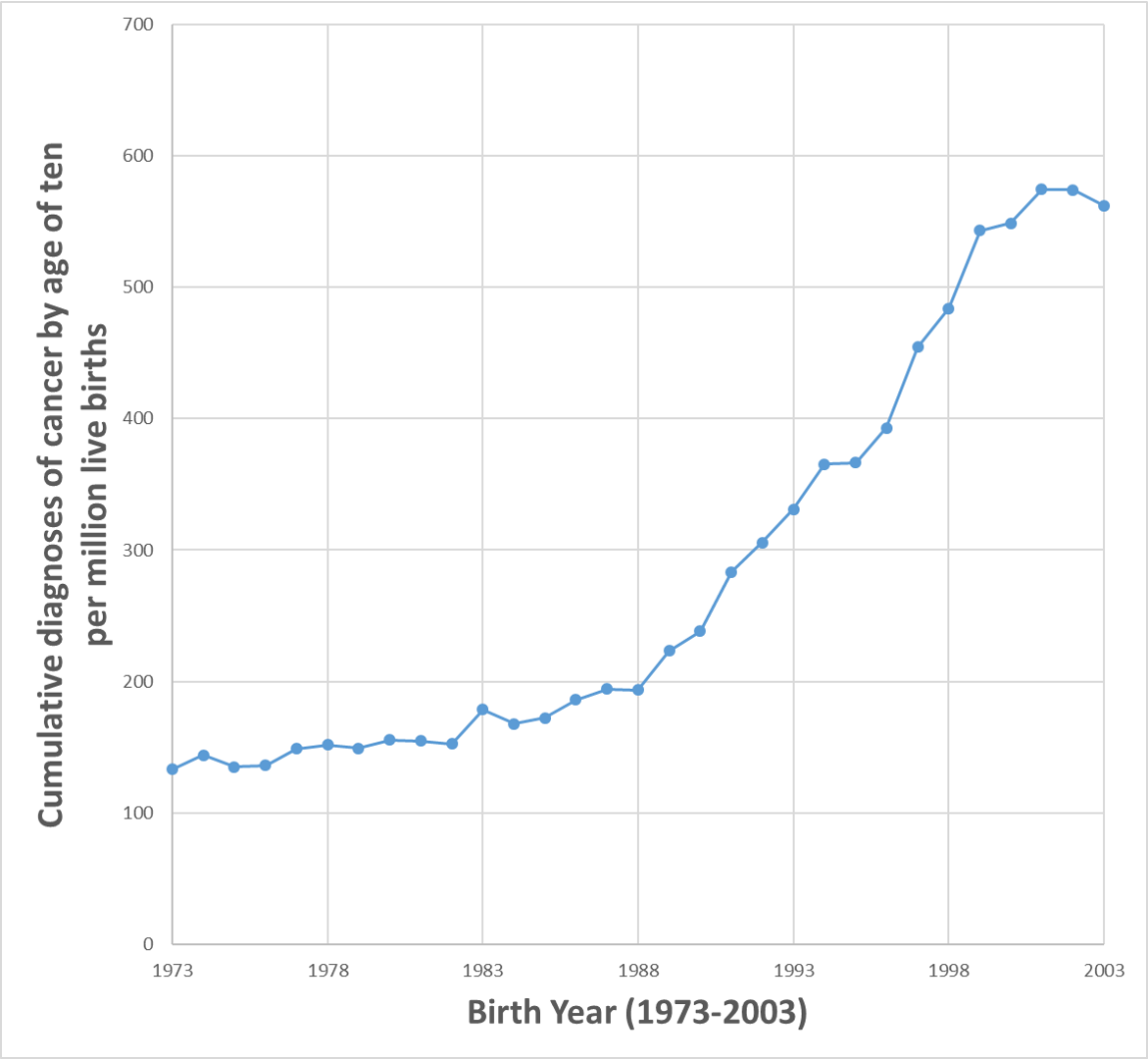


Figure 3: Cancer diagnoses by the age of ten correlated with U.S. cell phone subscriptions

Diagnoses of cancer in the U.S. per year of birth (1973-2003) by the age of 10 correlated with U.S. cell phone subscriptions.

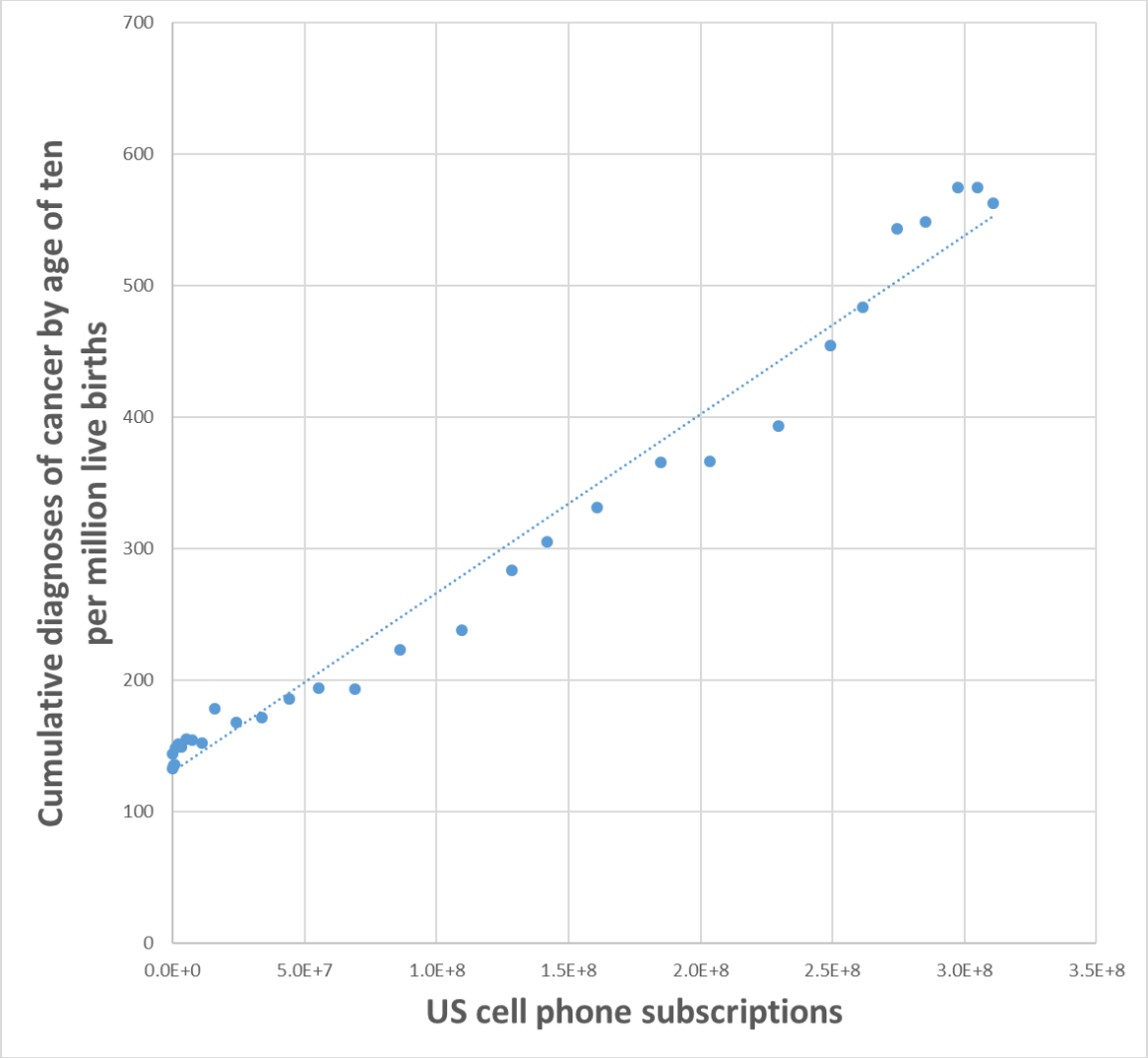


Figure 4: Glioma diagnoses by age of ten correlated with U.S. cell phone subscriptions

Diagnoses of glioma in the U.S. per year of birth (1973-2003) by the age of 10 correlated with U.S. cell phone subscriptions.

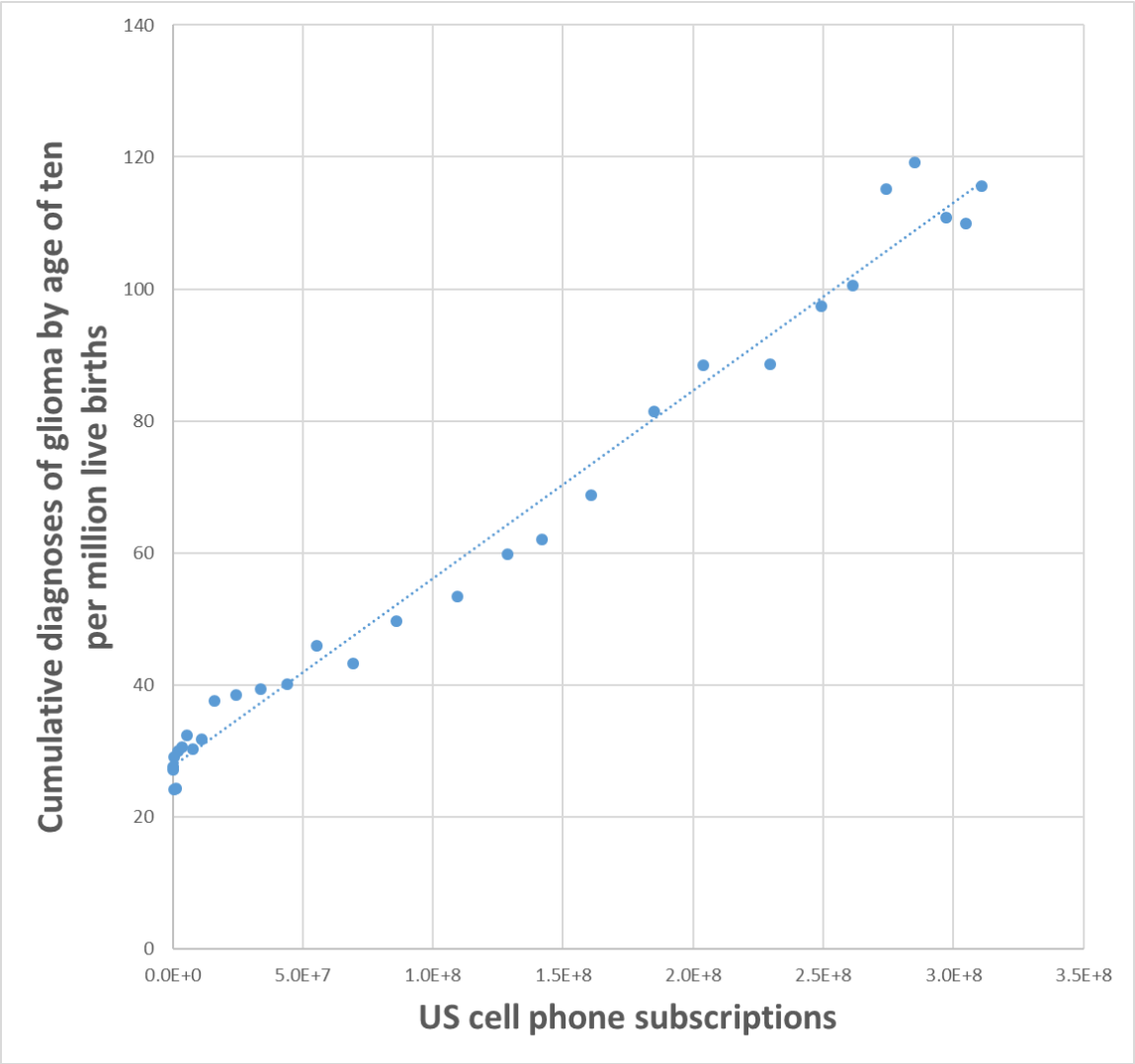
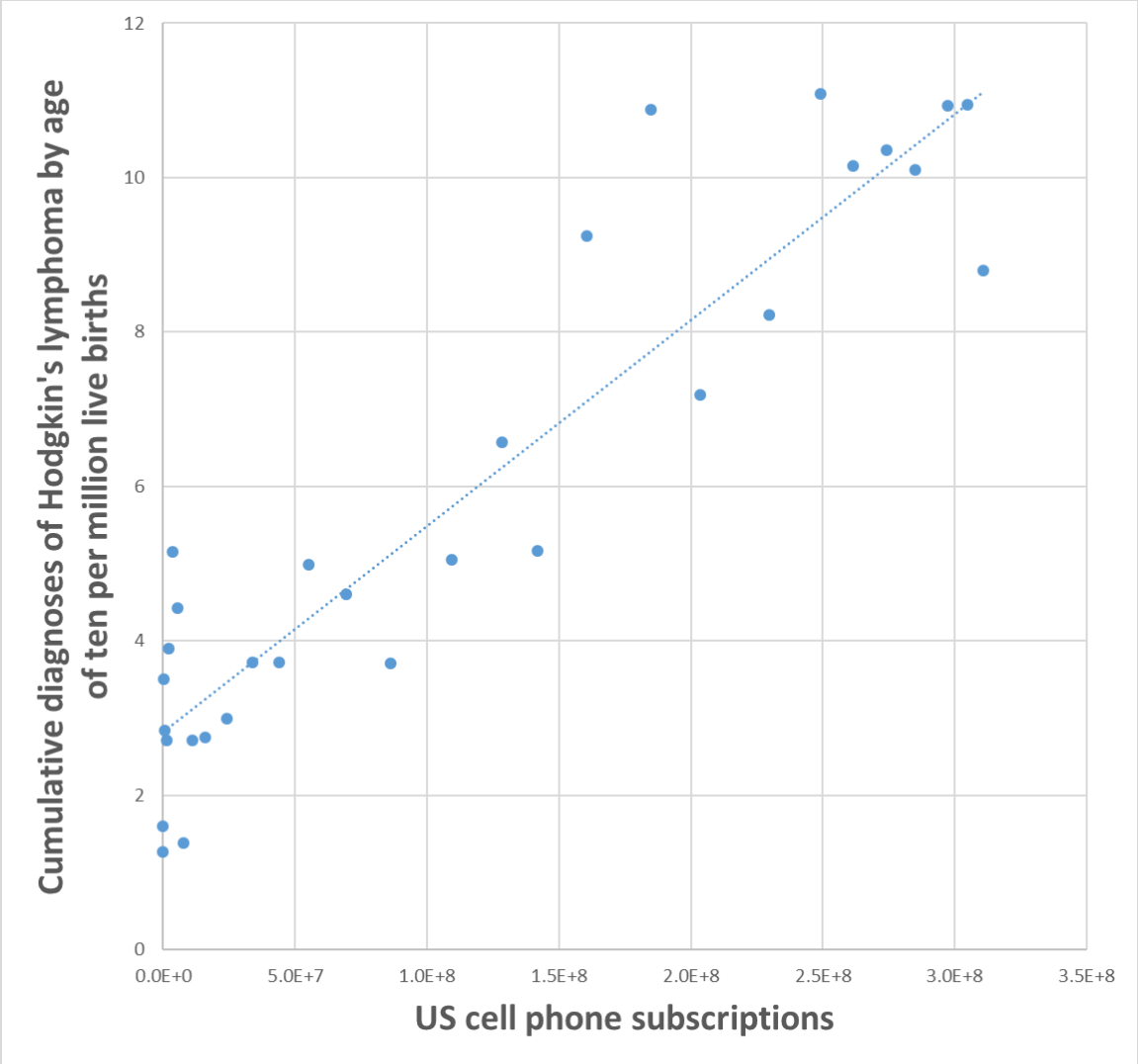


Figure 5: Hodgkin's leukemia diagnoses by age of ten correlated with U.S. cell phone subscriptions

Diagnoses of Hodgkin's lymphoma in the U.S. per year of birth (1973-2003) by the age of 10 correlated with U.S. cell phone subscriptions.



Discussion

The dramatic rise in cancer diagnosis rates in adolescents represents an unexpected major public health challenge. If wireless cellular technology is not causal in this increase, then it is urgent that the actual causal agent(s) be identified. Any such environmental agent(s) would be expected to demonstrate a higher correlation than those observed in Tab. 1 from 1973 to 2013, e.g., higher than $R^2 = 0.988$ for cumulative cancer diagnoses up to ages 7 and 8, with $p < 0.00001$, and in Tab. 2, e.g., higher than $R^2 = 0.985$ for gliomas up to age 10, also with $p < 0.00001$. Any such agent(s) would require a trend that matches the growth rate of U.S. cell phone subscriptions, to align temporally with the observed increase of cancer diagnosis rates.

Due to the urgency of these findings, an initial attempt was made to validate these correlations with data from other nations. Publicly available epidemiology data for cancer diagnoses from Australia, Canada, and the United Kingdom were examined and although diagnosis rates were found to be increasing, the data was binned by ranges of ages, which does not permit inclusion or a direct comparison to Tabs. 1 or 2. Access to detailed case data would permit cumulative diagnoses by age to be calculated for each year of birth, as required for either an expanded scope or a direct comparison. The New Zealand Ministry of Health generously provided all the data required for a direct comparison, however, the correlations found were not substantive (e.g., $p > 0.2$) due to the low population and number of diagnoses.

Some relevant factors have changed over the temporal scope of the correlations. Improvements in health care and diagnostic methods including medical imaging over the last few decades may account for some increased diagnosis rates. However, the increased diagnosis rate of Hodgkin's lymphoma in U.S. adolescents does not fit this interpretation, because it has been easily detected without these newer technologies (see Extended Data Table 5). Cellular technology has also changed from analog to digital phones, with frequencies generally increasing from 850 MHz to include 1900 MHz, with differing power outputs. With the introduction of smartphones, frequent data transmissions can occur even when no voice call is active. The cellular subscription data that was utilized does not detail the various types of modulations or peak power outputs of the subscribers' devices. Although these factors are acknowledged to introduce additional variables over time, analysis of these are outside the scope of this paper.

Changes in immigration rates can also vary diagnosis rates based on live birth vital statistics. Annual reports of immigration statistics from both the U.S. Census Bureau and U.S. Department of Homeland Security (DHS) bin immigration data by ranges of ages, which does not permit adjustment of population totals by live births per year with foreign-born totals by year of birth and age as required for correlation with cumulative diagnoses per year of birth as detailed in epidemiological case data [20,21]. For instance, in 2013 there were 79,953 lawful permanent residents admitted to the U.S. from the age of 0 to 9, which is equivalent to 2.0% of the live births in 2013. However, the foreign-born population of 10-year-olds in the U.S. would need to exceed the native-born population by 323% in 2013 for cancer diagnosis rates to remain unchanged in Fig. 2. While including foreign births of immigrants would refine the quantitative results reported here, the qualitative results would remain unchanged. A Freedom of Information Act request was submitted to the U.S. DHS for the data required from 1973 to 2013 to adjust the

population model from per million live births to per million, but these requests can take several to many months, and the requested data was not provided by the time of this submission. If approved, future analysis could include U.S. immigration data.

The high correlation of U.S. cell phone subscriptions with a dramatic increase of adolescent cancer diagnosis rates brings into question the current electromagnetic emissions safety standards utilized by the consumer electronics industry. Unfortunately, the effects of electromagnetic emissions on human tissues and intracellular processes are not fully understood. Although the transmission energies utilized are thought to be insufficient to cause ionization of bonds in organic tissues, any interference with genome repair mechanisms, or possibly other operations during transcription (e.g., where nitrogenous bases have been weakened by prior damage), may be sufficient to introduce additional pathogenic mutations in human DNA. Adolescents have large portions of tissues that are growing and cells that are undergoing mitosis at any given time, and may be more susceptible to some environmental pathogens, unlike adults that have relatively static populations of some tissues (e.g., neurons and glia) and slow regenerative rates for others (e.g., adipocytes). Until the processes involved are better understood, it would be prudent to consider establishing public safety guidelines that minimize electromagnetic emissions exposure, especially to pregnant women and adolescents. This adversity also presents an opportunity for the consumer electronics industry to develop safer wireless transmission technologies utilizing different frequencies or portions of the electromagnetic spectrum with reduced transmission energies and potentially different geometries for geographically distributed cellular areas. In fact, many of the currently utilized technical standards and protocols could be readily adapted to different waveforms and/or frequencies.

Methodology

Epidemiology data from the National Cancer Institute was utilized for the U.S. population from 1973 to 2013 [1]. This clinical data has birth and diagnosis dates temporally truncated to the year to protect the identity of individuals, which precludes sub-annual analysis. Live birth totals for males and females in the U.S. were utilized from vital statistics reports for each year from 1973 through 2013 to provide a population model for clinical data [22,23,24,25]. (See Extended Data Table 1.)

U.S. cell phone subscription totals were obtained from the Cellular Telephone Industry Association (CTIA) industry statistics for 1985-1999, and from the International Telecommunications Union Development Sector (ITU-D) for 2000-2013 [26,27]. Subscription data for 1984 and earlier was not found but assumed to be less than the total for 1985, and was therefore rounded to zero (i.e., the nearest million subscriptions). (See Extended Data Table 2.)

Cumulative diagnoses of cancer were calculated for each year of birth from 1973 to 2013 for each year of age up to ten. Live birth totals from vital statistics were utilized to calculate diagnoses rates per million live births. (See Extended Data Table 3.) Cumulative diagnoses of cancer for each year of birth and year of age up to ten were then correlated with U.S. cell phone subscriptions. When using cumulative diagnoses per year of birth, the number of data points

available for correlation can be less than the total number of diagnoses when multiple diagnoses occur at the same age for patients born in the same year.

Histologies were selected for review representing several tissue types including adipocytes, bone marrow cells, hepatocytes, lymphocytes, neurons & glia, and vascular endothelial cells. Cumulative diagnoses of these histologies, including liposarcoma, osseous and chondromatous neoplasms, giant cell tumors, miscellaneous bone tumors, odontogenic tumors, hepatocellular carcinoma, malignant lymphoma, Hodgkin's lymphoma, mature B-cell lymphoma, precursor cell lymphoblastic lymphoma, T & NK-cell lymphoma, glioma, meningioma, nerve sheath tumors, neuroepitheliomatous neoplasms, and angiosarcoma, were calculated for each year of birth from 1973 to 2003 through the age of ten. Vital statistics were utilized to calculate diagnoses rates per million live births. Cumulative diagnoses of each histology for each year of birth through the age of ten were then correlated with U.S. cell phone subscriptions.

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Author Contributions

Both authors contributed to data collection, analysis, and writing of this report.

Competing Financial Interests

The authors declare no competing financial interests.

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Supplementary Information File

Extended Data Table 1: U.S. live births 1973-2013

Year	Male	Female	Total
1973	1,608,326	1,528,639	3,136,965
1974	1,622,114	1,537,844	3,159,958
1975	1,613,135	1,531,063	3,144,198
1976	1,624,436	1,543,352	3,167,788
1977	1,705,916	1,620,716	3,326,632
1978	1,709,394	1,623,885	3,333,279
1979	1,791,267	1,703,131	3,494,398
1980	1,852,616	1,759,642	3,612,258
1981	1,860,272	1,768,966	3,629,238
1982	1,885,676	1,794,861	3,680,537
1983	1,865,553	1,773,380	3,638,933
1984	1,879,490	1,789,651	3,669,141
1985	1,927,983	1,832,578	3,760,561
1986	1,924,868	1,831,679	3,756,547
1987	1,951,153	1,858,241	3,809,394
1988	2,002,424	1,907,086	3,909,510
1989	2,069,490	1,971,468	4,040,958
1990	2,129,495	2,028,717	4,158,212
1991	2,101,518	2,009,389	4,110,907
1992	2,082,097	1,982,917	4,065,014
1993	2,048,861	1,951,379	4,000,240
1994	2,022,589	1,930,178	3,952,767
1995	1,996,355	1,903,234	3,899,589
1996	1,990,480	1,901,014	3,891,494
1997	1,985,596	1,895,298	3,880,894
1998	2,016,205	1,925,348	3,941,553
1999	2,026,854	1,932,563	3,959,417
2000	2,076,969	1,981,845	4,058,814
2001	2,057,922	1,968,011	4,025,933
2002	2,057,979	1,963,747	4,021,726
2003	2,093,535	1,996,415	4,089,950
2004	2,104,661	2,007,391	4,112,052
2005	2,118,982	2,019,367	4,138,349
2006	2,182,764	2,082,791	4,265,555
2007	2,208,071	2,108,162	4,316,233
2008	2,173,625	2,074,069	4,247,694
2009	2,113,739	2,016,926	4,130,665
2010	2,046,561	1,952,825	3,999,386
2011	2,024,068	1,929,522	3,953,590
2012	2,021,800	1,931,041	3,952,841
2013	2,013,108	1,919,073	3,932,181

Extended Data Table 2: Industry data for U.S. cell phone subscriptions 1983-2013

Year	Quantity
1983	-
1984	-
1985	340,213
1986	681,825
1987	1,230,855
1988	2,069,441
1989	3,508,944
1990	5,283,055
1991	7,557,148
1992	11,032,753
1993	16,009,461
1994	24,134,421
1995	33,785,661
1996	44,042,992
1997	55,312,293
1998	69,209,321
1999	86,047,003
2000	109,478,031
2001	128,500,000
2002	141,800,000
2003	160,637,000
2004	184,819,000
2005	203,700,000
2006	229,600,000
2007	249,300,000
2008	261,300,000
2009	274,283,000
2010	285,118,000
2011	297,404,000
2012	304,838,000
2013	310,698,000

Extended Data Table 3: Cumulative number of cancer diagnoses by age ten per million live births (1973-2013)

Year of Birth	Diagnoses
1973	132.9
1974	144.0
1975	134.9
1976	136.1
1977	148.8
1978	151.8
1979	149.1
1980	155.6
1981	154.9
1982	152.4
1983	178.6
1984	167.9
1985	172.0
1986	186.1
1987	194.3
1988	193.6
1989	223.5
1990	238.3
1991	283.4
1992	305.5
1993	331.2
1994	365.3
1995	366.4
1996	392.9
1997	454.5
1998	483.8
1999	543.3
2000	548.7
2001	574.5
2002	574.1
2003	562.4

Extended Data Table 4: Cumulative number of glioma diagnoses by age ten per million live births (1973-2013)

Year of Birth	Diagnoses
1973	27.1
1974	27.5
1975	24.2
1976	29.0
1977	24.3
1978	30.0
1979	30.6
1980	32.4
1981	30.3
1982	31.8
1983	37.6
1984	38.4
1985	39.4
1986	40.2
1987	45.9
1988	43.2
1989	49.7
1990	53.4
1991	59.8
1992	62.0
1993	68.7
1994	81.5
1995	88.5
1996	88.7
1997	97.4
1998	100.5
1999	115.2
2000	119.2
2001	110.8
2002	109.9
2003	115.6

Extended Data Table 5: Cumulative number of Hodgkin's lymphoma diagnoses by age ten per million live births (1973-2013)

Year of Birth	Diagnoses
1973	1.6
1974	1.3
1975	3.5
1976	2.8
1977	2.7
1978	3.9
1979	5.2
1980	4.4
1981	1.4
1982	2.7
1983	2.7
1984	3.0
1985	3.7
1986	3.7
1987	5.0
1988	4.6
1989	3.7
1990	5.1
1991	6.6
1992	5.2
1993	9.2
1994	10.9
1995	7.2
1996	8.2
1997	11.1
1998	10.1
1999	10.4
2000	10.1
2001	10.9
2002	10.9
2003	8.8